Forest Sciences

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Characterizing Old Growth and Strategies for Old Growth Management in the Sub-Boreal Spruce Zone

Research Issue Groups:

Forest Biology

Forest Growth

Soils

Wildlife Habitat

Silviculture

Ecosystem Inventory and Classification

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Extension

Background

"Old growth" means different things to different people. Ecologists and silviculturists recognize old growth as a post-maturity phase of natural stand development, defined by the population dynamics of the tree layer (Oliver and Larson 1990). Old-growth forest tends to be dominated by "gap dynamics" or single-tree replacement processes. This means that old-growth stands typically have trees that originated as secondary recruitment (a replacement cohort) beneath the canopy, having gradually replaced trees which initially established after fire. Old-growth stands thus have internal heterogeneity reflecting the diverse origins of individual trees. Characteristic structural attributes include large, old trees, some of which are dying (becoming snags) and falling (becoming logs and leaving canopy gaps). In addition, there are many young trees of all ages and sizes, which contribute to a multi-layered canopy and complex vertical and horizontal spatial pattern

Figure 1. Representative interior of an old sub-boreal spruce stand.

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(Figure 1). This fine-scaled structural diversity is responsible for old growth's role as favoured habitat for many animal species, such as marten. But critical values for distinguishing old-growth status on the basis of tree size, age, or snag and log densities clearly differ among forest types (Pojar *et al.* 1992). Furthermore, the importance of each diagnostic attribute can vary with conservation or silvicultural objectives.

Skeptics suggest that the concept of "old growth" is inapplicable to boreal and sub-boreal regions. Northern landscapes are subject to frequent stand-initiating wildfires, with a mean return interval of approximately 125 years estimated for the Sub-Boreal Spruce (SBS) zone (Anonymous 1995). Likewise, extensive insect outbreaks (such as spruce budworm, bark beetles, and tent caterpillars) are common stand-level disturbances. This means that few boreal and sub-boreal stands persist long enough to develop into true old growth. As forests are brought under management, industrial timber rotations (80 to 120 years) likewise preclude the development of old-growth forest stands. These factors cumulatively contribute to the general rarity of old-growth stands in boreal landscapes, and make them exceptionally valuable to biodiversity conservation at several scales.

This Research Note explores the potential for managing SBS forests for old-growth attributes from three perspectives. First, we describe research that investigated the long-term dynamics of natural SBS stands, and a scoring system designed to ascertain whether or not you currently have old-growth stands. Secondly, that same scoring system is used to identify structural attributes which should be retained in order to maintain old-growth characteristics after partial cutting of stands. Thirdly, landscape- or forest-level alternatives for the maintenance of old growth are discussed.

Identifying Old-Growth

Sub-boreal Spruce Stand Dynamics

The B.C. Ministry of Forests sponsored two field studies to learn more about the natural stand dynamics of Sub-Boreal Spruce forests (Kneeshaw 1992, Clark 1994), and to derive more concrete definitions of old growth in this biogeoclimatic zone. The stands examined in both studies were from the Babine variant of the moist-cold SBS subzone (SBSmc2), near Houston and Smithers. Kneeshaw's study was limited to mesic sites supporting stands with interior hybrid spruce as a component. Sample stands ranged in age from approximately 100 to 350 years old. Methods of analysis involved a combination of stand reconstruction and chronosequence approaches (Oliver and Larson 1990). All trees, saplings, seedlings, snags and logs within each plot were described, measured and mapped, and all trees were aged. Similar methods were used by Clark (1994), but not all trees were aged, and not all of his stands had spruce as a component. His stands spanned a wider chronosequence, aged 11 to 438 years since stand initiation.

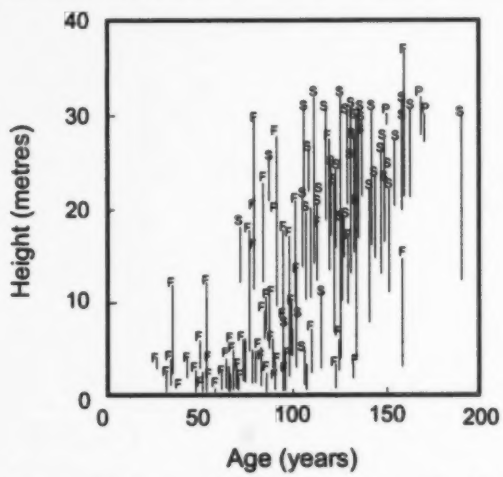

Figure 2. Canopy profile generated by individual trees, ordered by tree age, in a 188 year old stand. Species are denoted by letter: F = subalpine fir, S = interior spruce, and P = lodgepole pine. Location of each symbol indicates total tree height, and the vertical line represents length of the live crown. Modified from Kneeshaw (1992).

Charcoal and ash layers demonstrated that all sampled stands initially established after catastrophic fires. In all cases, the natural regeneration period after fire was quite long, taking 50 to 100 years for trees to fully occupy the site. Many stands showed evidence of trembling aspen in the early stages of stand development. Lodgepole pine was more abundant in younger stands, and subalpine fir was progressively more abundant in older stands. Both studies also found stands that had been dominated by subalpine fir from the outset, indicating the presence of alternative successional trajectories. Understory regeneration was observed in the older stands, most of it patchy and associated with the periphery of canopy gaps rather than gap centres. This pattern may be due to greater snow accumulation or brush competition in canopy gaps. Subalpine fir regeneration was always more abundant than that of interior spruce, but the patterns of growth and mortality inferred from Kneeshaw's study suggest that spruce was more successful at being recruited into the canopy (Figure 2). Thus spruce often maintains itself as a dominant member of the canopy without the need for stand-destroying disturbance. Stands in which secondary spruce regeneration appeared successful were generally characterized by minor, small-scale

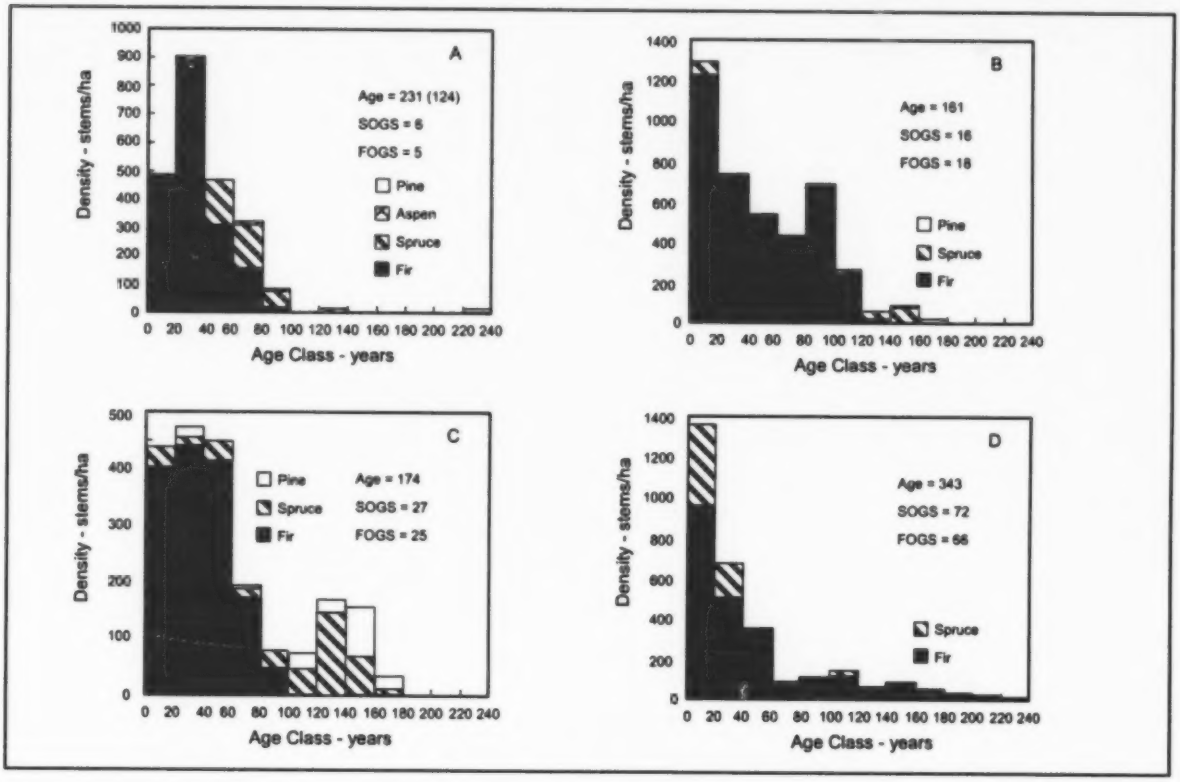

Figure 3. Examples of different stand age class distributions encountered among mature and old SBSmc2 stands, shown in order from lowest to highest old-growth scores (SOGS = structural old-growth score, FOGS = functional old-growth score; each has a maximum score of 100, as per Table 1). ***Stand "a"*** *still has a unimodal age structure (beginning to stratify into a bimodal form), reflecting a long period of post-fire recruitment.* ***Stand "b"*** *is multi-modal or random in age structure because of fluctuations in subalpine fir recruitment.* ***Stand "c"*** *is bimodal in age structure, with the secondary cohort consisting primarily of subalpine fir.* ***Stand "d"*** *exhibits a reverse-J age class distribution characteristic of uneven-aged, self-sustaining old-growth stands. Note that old-growth scores are not simply a function of stand age. Modified from Kneeshaw (1992).*

releasing disturbances and break-up of the overstory, often due to spruce bark beetle or root rot.

Indicators and Thresholds

The functional "old growthness" of SBS stands can be effectively measured by assessing the relative proportion of the stand's basal area found in replacement and colonizing cohorts, *i.e.*, by calculating cohort basal area ratios. In functionally older stands, the replacement cohort is more dominant and is responsible for much of the current stand dynamics. Such stands were sometimes younger than others that did not share gap dynamics behaviour. Analysis of stand age structure (typically portrayed as stem density charted against stem age classes) assists in the interpretation of stand dynamics and old-growth status. Unimodal or single-peaked stand structures were characteristic of young stands (Figure 3a), and gradually shifted to bimodal or multi-modal distributions in older stands (Figure 3b, 3c), and to strongly right-skewed or negatively sloped distributions in the oldest stands (Figure 3d). Stands that have "reverse-J" shaped or negative exponential distributions are most representative of old-growth conditions.

It is difficult to determine the age of every tree (including small trees and subcanopy regeneration) in sample plots, to identify the critical age for distinguishing initial and replacement cohorts, and to calculate the basal area ratios for those cohorts. Kneeshaw (1992) used Principal Components Analysis (PCA) to correlate easily measured stand structural attributes with cohort basal area ratios. The results confirmed that structural components can collectively be used to identify old-growth stands. Attributes most indicative of old-growth status in the SBSmc2 are stand age, numbers of large logs, regeneration density, and numbers of large snags (Table 1). Visual inspection of the data revealed threshold or cut-off values separating "mature" from true "old-growth" stands. These relationships were combined in the development of Table 1, which allows one to score

Table 1. Old-Growth Rating Guide for SBSmc2 Spruce Stands*

Stand Attribute	Critical Value	Structural Weighting Factor	Structural Score?	Functional Weighting Factor	Functional Score?
Stand Age, years	175	12		23	
Basal Area, m2/ha	50	6		8	
Tree (>7.5 cm dbh) Density, #/ha	800	6		5	
Snag Density, #/ha	200	10		1	
Regen. (<2m tall) Density, #/ha	7000	7		14	
Total Tree Volume, m3/ha	500	6		8	
Total Snag Volume, m3/ha	80	11		6	
Total Log Volume, m3/ha	200	7		10	
Large Tree (>1.0m3) Density, #/ha	220	9		4	
Large Snag (>1.0m3) Density, #/ha	25	13		7	
Large Log (>1.0m3) Density, #/ha	100	13		14	
SUM	–	100		100	

**Instructions: For those attributes that meet or exceed critical values, copy the appropriate weighting factor into the Structural Score and Functional Score columns; else enter zero. Sum each column for an index of "old growthness" according to the structural or functional thresholds. The two scores can be averaged for an overall, general purpose index. If data on all attributes are not available, express the sum as a percentage of the potential score of those attributes used. Scores of 0 to 33 denote stands that are clearly not old growth; scores of 67 to 100 denote stands that clearly are old growth; any score > 50 indicates a stand that is more "old growth" than "mature" in character.*

any given stand according to its attainment of various measurable thresholds.

Structural and functional scores are well correlated, but they can highlight some important differences among stands. A high structural old-growth score (SOGS) may be important for wildlife habitat or for visual aesthetics. Conversely, a high functional old-growth score (FOGS) may be more important for silvicultural prescriptions or for the designation of benchmark ecological reserves. It should be stressed that stand development occurs along a continuum, with old-growth status likewise a continuous variable, not really a categorical or threshold-based one.

Managing Old Growth at the Stand Level

It has been widely suggested that forest stands could be managed for old-growth attributes, while still harvesting some timber (Hansen et al. 1991, Perry 1994). Indeed, the creation of canopy gaps could accelerate the attainment of old-growth status in mature stands, similar to the impact of bark beetles and root rot pockets in some of the stands studied.

Let us assume that most of the thresholds identified in Table 1 would have to be maintained in order to sustain a stand's role as an old-growth ecosystem. This would require stands to retain 800 trees/ha, with a basal area of 50 m2/ha and total volumes of 500 m3/ha (or net merchantable volumes of 350 to 425 m3/ha). We estimate that these criteria would allow some timber extraction (up to 135 m3/ha, net merchantable volume) in approximately half of the old-growth stands in the SBSmc2. Harvesting could be conducted as part of a single-tree or group selection system designed around an uneven-aged management model. More important, however, would be the retention of snags (200/ha, 80 m3/ha) and logs (200 m3/ha), especially all large ones (>1.0 m3 per piece, or 25 m tall trees with dbh > 35 cm). For half of the old-growth stands we inspected, basal area removals of approximately 6 m2/ha every 20 years are likely to be ecologically and silviculturally sustainable without technically compromising old-growth values.

These suggestions support Biodiversity Guidebook (Anonymous 1995) recommendations that partial cutting systems be used to maintain old-growth attributes in some spruce and fir stands, and suggest that more than the recommended 70% of stand volume and stand attributes should be retained to meet old seral stage objectives.

Alternatives to clear-cut management are suggested by the ability of the forest to maintain itself in the absence of stand-level disturbance. Subalpine fir is prolific at producing seedlings, but the greater recruitment of spruce into the canopy suggests that both species could successfully be managed using partial cutting methods. Subalpine fir was the only species to consistently exhibit an all-aged population structure required for formal uneven-aged management.

Such stand-level old-growth management prescriptions might be suitable for Special Management Areas, small woodlots and private land holdings where some timber harvest is mandated. Whether such low harvest levels are sufficient to economically justify access development and stand entry must be determined on a case by case basis, and worker safety must be carefully protected.

Landscape Approaches

Old Growth Rarity and Protection

The ubiquitous history of wildfire in the SBS, and the problems of undertaking partial cutting noted above, suggest that other strategies for maintaining old-growth in the landscape are required. The first option is simply to protect some old-growth forests, or to exclude them from the operable forest land base. The amount of land to set aside in this manner depends on various conservation and wilderness management objectives, but also depends on the local rarity (and hence value) of old growth. We suggest that 175 years approximates the critical age for recognizing old-growth stands in the SBSmc2 (Table 1), greater than the 140 year age recommended in the Biodiversity Guidebook. Currently, old forests

are mapped by the MoF Inventory Branch as "Age Class 8" (140 to 250 years old) or "Age Class 9" (>250 years of age). More detailed age class identification is clearly needed in the SBS in order to rapidly assess the abundance of old-growth resources. In one subset of the SBSmc (west of Whitesail Reach of Ootsa Lake), 47% of the forest is greater than 180 years old (Figure 4a). In contrast, only 14% of the Burns Lake TSA (634,000 ha, mostly SBSdk) consists of stands >180 years old (J.D. Steventon, *unpub. data*). In the SBSmk NW of Prince George, stands >180 years old occupy only 2.5% of the landscape (Andison 1996).

Thus there is considerable variation in the abundance of old-growth in the SBS, reflecting regional differences in precipitation and logging history. Forest inventory standards are being updated to higher levels of precision, and all old stands should be inspected on the ground to confirm their old-growth status (as per Table 1). The Biodiversity Guidebook recommends that 50% to 75% of the natural percentage of old seral stages in the SBS should be retained, to a minimum of 11% (in lower and intermediate biodiversity emphasis areas) or 16% (in higher biodiversity emphasis areas). This means that all old stands should be deferred from logging in some areas while there is considerable room for further old-growth harvesting elsewhere. However, the fate of old stands deferred from cutting is not easily predictable. Most current old-growth will eventually be renewed by wildfire, bark beetles, root rot, or windthrow, while a very small proportion could persist indefinitely.

Rotation Management

If old-growth forest is to be a renewable resource, and if we are to ensure the presence of old-growth stands throughout managed forests, then old growth must be explicitly planned for. Under a regime of even-aged management, this is most simply accomplished by extending rotations to include an old-growth stage prior to harvest. The necessary rotation length can be calculated from the followingequation (Perry 1994):

$$R = L / (1-p)$$

where R is the rotation length, L is the length of time required to return to old-growth status, and p is the proportion of old-growth desired for a landscape. For example, if it takes 175 years to achieve old-growth status, and if you want 11% of a managed forest to be kept in old-growth, then R = 175 / (1-0.11) = 197 years as a recommended (uniform) rotation length (*e.g.*, Figure 4b). The proportion of the landbase in any one age-class is then simply:

$$F_{AC}=W/R$$

where F_{AC} = the fraction (0 to 1) of the landscape in any given age-class, A, W = the width of age-classes (years), and R = rotation length (years), and where R is an even multiple of W.

The universal application of long rotations across the forest land base, however, could cause some problems: forests would have to be protected long after fires and insects are likely to attack them, most crop trees would be accruing wood at rates much less than their potential, and overall harvest levels would have to reduced in proportion to the degree that rotations are extended.

An alternative is to use extended rotations for only some stands, with rotation lengths varying from industrial standards (*e.g.*, 120 years) to the age of the oldest natural stands found on the landscape (240 years or more). Reflecting the increasing cumulative probability of disturbance with increasing age, and the typical age structure of forest stands in the natural landscape, decreasing proportions of forest area should be managed to the maximum age for the landscape (Figure 4b). Such a "tapered" age profile or "variable rotation" management plan can be designed to maintain and generate stands attaining a range of desired ages. Table 2 provides guidance for the potential extension of 120 year rotations. Variable rotation management results in a standard regulated forest for most stands, with successively fewer stands managed for greater and greater ages. As formulated in Table 2, this design generates an age profile which tapers linearly to the maximum age desired (Figure 4b), facilitating a combination of timber production and biodiversity conservation.

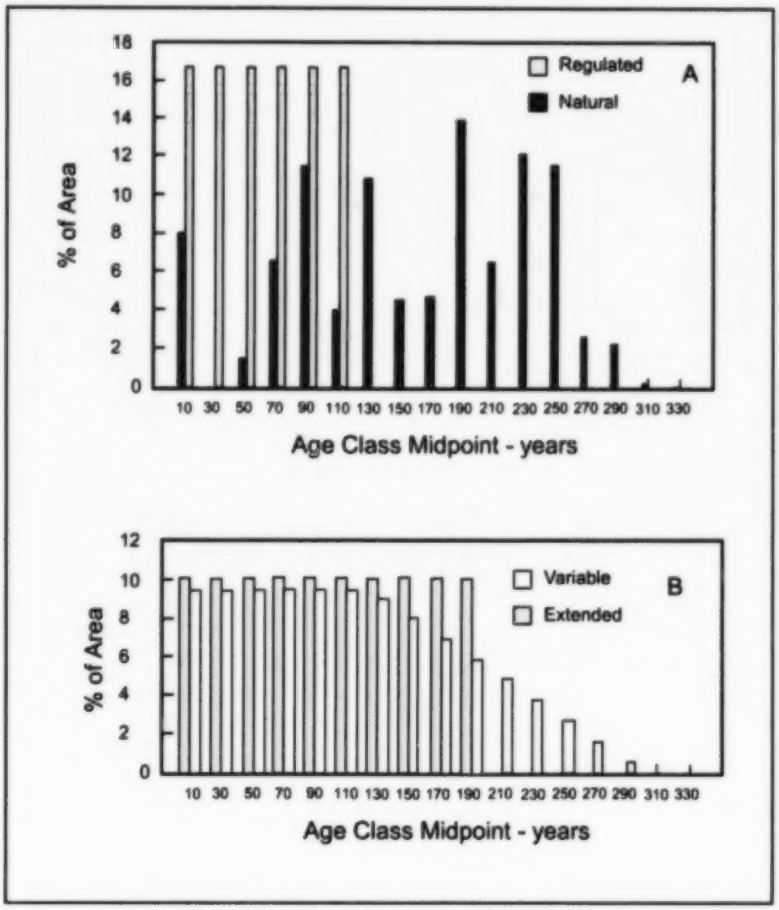

*Figure 4. Alternative age-class distributions for landscape management. **(a)** The natural distribution of 28,714 ha of SBSmc west of Whitesail Reach, and the age structure for a fully regulated forest with 120 year rotations. **(b)** A fully regulated forest with all rotations extending to 200 years, or variable rotations extending from 120 to 300 years (as per the last line of Table 2).*

Intermediate Approaches

Another approach to old-growth management may be to retain old-growth features at scales intermediate between stand and landscape levels. In particular, the retention of small patches of forest (containing green trees in multiple canopy layers, snags and logs) strategically located within a cut-block very effectively mimics the patchy nature of wildfire, and can conserve habitat attributes important to biodiversity (Hansen et al. 1991). Clark (1994) found that 28% of the stands he sampled had trees that survived stand-initiating wildfires. The patch retention system (described in another Extension Note in this series; Coates and Steventon 1994) aproximates this phenomenon in a safe and efficient manner.

A combination of approaches to old-growth management is clearly the most prudent strategy. Some old growth in every management area should be protected from logging, while some old stands can be partially cut under a selection system. In order to accelerate the development of old-growth stands, some mature stands can also be managed to create canopy gaps, snags, and logs, or to improve the growth of a few dominant trees so that they more rapidly achieve massive stature. Longer rotations throughout the forest will aid in the attainment of old-growth features, and extending the rotation lengths of selected stands will further ensure the presence of old growth on the landscape.

Summary

In the absence of wildfire, forest stands in the SBS can achieve great age, but the rarity and conservation value of this old-growth resource requires special management considerations. Recent studies have investigated the long-term dynamics of forest stands in the SBSmc2, and this work was used to develop a score-card for evaluating the old-growth status of individual stands. Some of these stands are worthy of protection, while others could be partially cut without compromising

Table 2. Forest age class distributions (percentages of forest area in different age classes) under variable rotation lengths, extending from standard 120 year rotations to maximum ages of 140 to 300 years. Values are percent of landscape in forest age classes (beyond 120 years) for each of several alternative maximum ages. See Figure 3b.

Desired Max. Age	Age Class. Years									
	<120*	121-140	141-160	161-180	181-200	201-220	221-240	241-260	261-280	281-300
120	16.7									
140	15.4	7.7								
160	14.3	10.7	3.6							
180	13.3	11.1	6.7	2.2						
200	12.5	10.9	7.8	4.7	1.6					
220	11.8	10.6	8.2	5.9	3.5	1.2				
240	11.1	10.2	8.3	6.5	4.6	2.8	0.9			
260	10.5	9.8	8.3	6.8	5.3	3.8	2.3	0.8		
280	10.0	9.4	8.1	6.9	5.6	4.4	3.1	1.9	0.6	
300	9.5	9.0	7.9	6.9	5.8	4.8	3.7	2.6	1.6	0.6

* Percent of Landscape in each of the six 20-year age classes up to 120 years of age

old-growth values if critical stand attributes are retained. More appropriate solutions over the landscape include generally longer rotations, extended rotations for some stands, and the protection of old-growth features in small patches retained within cut-blocks.

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